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# Olives Pomace as Renewable Energy Source

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***Abstract*— This research involves analyzing and designing a prototyping system that uses renewable energy source to produce an electrical power. According to the limitation of nonrenewable resources, the main objective of this research is to contribute in solving the lack of renewable power supplies in Gaza strip. This research is based on using olives pomace as a source of energy in order to heat water and generate steam for electric power generation. Steam generator prototype was completed. Experiments were performed on this prototype to investigate the system. A tesla turbine was designed and manufactured to convert the steam power to mechanical energy, and then a DC generator was selected to convert the mechanical power to electrical power. After doing various experiments, the system shows that the olives pomace is a good power source with low cost and very high heat value.**

***Keywords*—Olives pomace; biomass; thermochemical process; biochemical process; Tesla turbine; boiler; heat value**

## I. INTRODUCTION

According to the limitations of nonrenewable sources and the big problems which leaves in the ground, the governments in all over the world looking for new renewable energy sources which meet their needs in the future.

Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat and biomass. Examples include forest residues (such as dead trees, branches and tree stumps), yard clippings, wood chips and even municipal solid waste. Olive waste is one of the biomass solid wastes which can be used as a renewable energy source. The olive waste is produced by production of olive oil as unusable solid waste, but has high heat value. This research is focusing on olive waste as renewable energy source in Palestine.

In Palestine, olives occupies about 45% of agricultural land and 16,000 tons of olive oil produced per year, which means that about 80,000 tons of olive waste produced per year. Gaza produce about 2.6% of this quantity of olive oil. In other side, from 0.23kg approx. of dried olive pomace 1kWh can be produced [1]. This means that, Palestine has an energy resource called olives pomace and this resource can be consumed for power generation.

According to the previous motivation, the goal of this research is to generate a steam power from olives pomace.

To generate electrical power, olives waste will burned under a closed boiler tank which contains water, then after sufficient amount of energy transmitted from olives waste to the boiler, the water will start boiling and turned onto steam, as the temperature rising, the amount of steam will increase and pressurized on the top of the boiler. This pressurized steam will be used to turn the plates of an external steam turbine in order to make the turbine shaft rotates the electric generator rotor and generating electric power. Fig. 1 shows a schematic for the system.

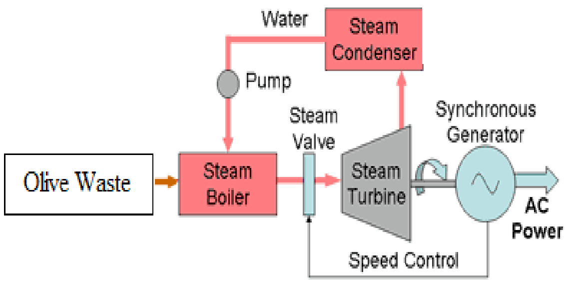



*Fig. 1: Schematic for Power Generation System*

This system in contrast nonrenewable energy is also considered “Clean energy”, because it does not produce toxins or pollutants [14] that are harmful to the environment. As well as the high price of nonrenewable energy resources increased rapidly in the last two decades, this is because the increasing in consumption of these fuels, Fig. 2 shows how the price of natural gas and fuel oil increased related to the cost of electricity [2].

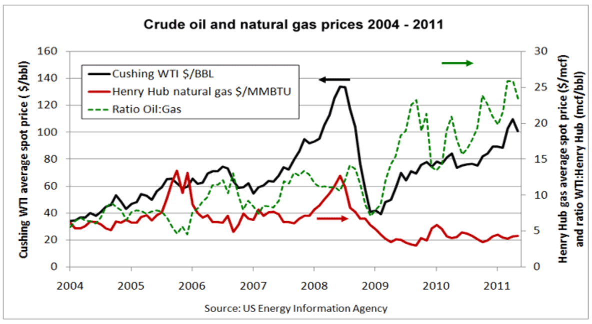



*Fig. 2: Price Curve of Fossil Fuels*

## II. Literature Review

Renewable energy sources are energy sources that are continually replenished. These include energy from water, wind, sun, geothermal and biomass sources such as energy of olives pomace. This study is concerned with olives pomace energy as a form of biomass energy sources.

### *A. Biomass*

Biomass is carbon based and is composed of a mixture of organic molecules containing hydrogen, usually including atoms of oxygen, often nitrogen and also small quantities of other atoms, including alkali, alkaline earth and heavy metals. These metals are often found in functional molecules such as the porphyrins which include chlorophyll which contains magnesium. Therefore biomass fuel is a renewable energy source [3].

When burnet the Carbone Dioxide (CO2) that is released into the atmosphere is only the CO2 that the plant would release when it died and decomposed. If fuel is purchased from a sustainable source it will not increase the Carbone Dioxide levels in the atmosphere (see Fig. 3). Biomass fuel is stored solar energy [4].

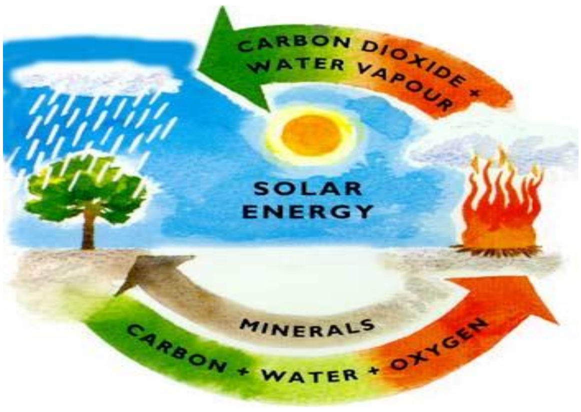



Fig.3: Carbon Dioxide from biomass cycle

There are five basic categories of biomass material:

- **Virgin wood:** from forestry, arboricultural activities or from wood processing.
- **Energy crops:** high yield crops grown specifically for energy applications.
- **Agricultural residues:** residues from agriculture harvesting or processing.
- **Food waste:** from food and drink manufacture, preparation and processing, and post-consumer waste.
- **Industrial waste and co-products:** from manufacturing and industrial processes like Olive pomace [3].

### *B. Olive Pomace*

Olive Pomace is the waste of the olive oil industry produced in tens of thousands of tons around the Mediterranean each year.

The olive pomace -the seeds and other solid parts of the olives - remains from olives after the oil extraction process. This brown mountain of waste grows during the weeks that the olives are pressed. Today, the thousands of tons of pomace are simply landfilled in most producing countries. Olive oil waste has always been one of the biggest problems associated with the industry [5].

This solid residue consist the major component of the olive biomass and thus it is the most important raw material needed for energy production.

Olive pomace is the residual paste after the olive oil extraction. It is constituted from a mixture of olive pit/stone, olive pulp and skin, as well as olive pomace plus the water added in the olive mills. Moisture percentage is important factor to known before using olive pomace. The moisture content is about 25-60% depending on the olive oil production process (Currently there are 3 technologies used to extract the oil [5]).

Energy density of olive pomace is approximately 18 MJ/kg (this value was taken as the average value from [6] and [7]) by comparing this value of heat density values shown in Fig. 4. It shows that olive pomace energy density is close to Ethanol energy density and higher than Wood energy density [8]. This large value of the energy is used in this study as a power source [10].

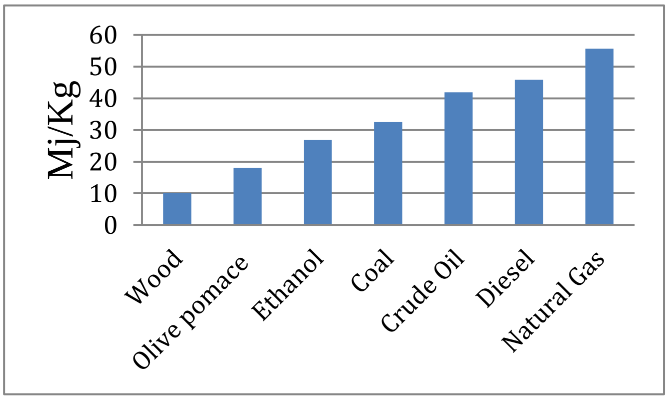



Fig. 4: Energy density comparison

## III. Olive Pomace Applications for Energy Production

Based on the percentage of the moisture in olive pomace, energy production can be classified for Thermochemical Process – which required moisture less than 50% and Biochemical Process – which required more than 50% [6].

### A. *Thermochemical Process*

There are three thermochemical process (Combustion, Gasification and Pyrolysis Process) used to produce energy [6]. Combustion Process is the simplest way to exploit olive solid residues for energy production is by direct combustion. Advantageous features of these kinds of boilers are the high thermal efficiency, the low operation cost and the need of non-frequent cleaning. Despite an often simple construction, most of the automatically fired boilers can achieve an efficiency of 80-90% and a CO emission of approximately 100ppm. The CO emission for natural gas is 1000ppm and for cocking gas is 800 ppm [10]. An important condition for achieving these good results is that the boiler efficiency during day-to-day operation is close to full load [6]. This method will be used in this research. Gasification Process and Pyrolysis Process are describe in [6].

### B. *Biochemical Process*

- **Anaerobic digestion:** is appropriate for high humidity treatment of virgin pomace, since a watery mean helps the process. The fuel used will be the one which could be digested, depending on the fat material, humidity, etc. Degasified two-phase pomace can be energy used in a biomass direct combustion thermoelectric power station. Biogas can be used to generate heat and/or power, as well as treated as a transport fuel. The digested residual, on the other hand, can be applied to the land-farm, instead of inorganic fertilizers to improve soil fertility [6].

- **Fermentation Processes:** Currently many technologies are being developed in order to obtain liquid bio fuels (ethanol) from lingo-cellulosic materials. Two main lingo-cellulosic materials sources exist in the olive oil sector: the two-phase or three-phase pomace, and the olive grove pruning. Research in three-phase pomace (which could be also extended to two-phase pomace), is done by separating the extracted pulp from the pit fragments, using temperatures between 190-236 ºC and time periods between 120-240 seconds. This process has achieved a selective solvolysis of their main compounds (lignin, hemi cellulose and cellulose [9]). After a fast auto hydrolysis process (steam explosion) the result is one soluble and another insoluble fragment. Fig. 5 shows the conversion routes for olive pomace.

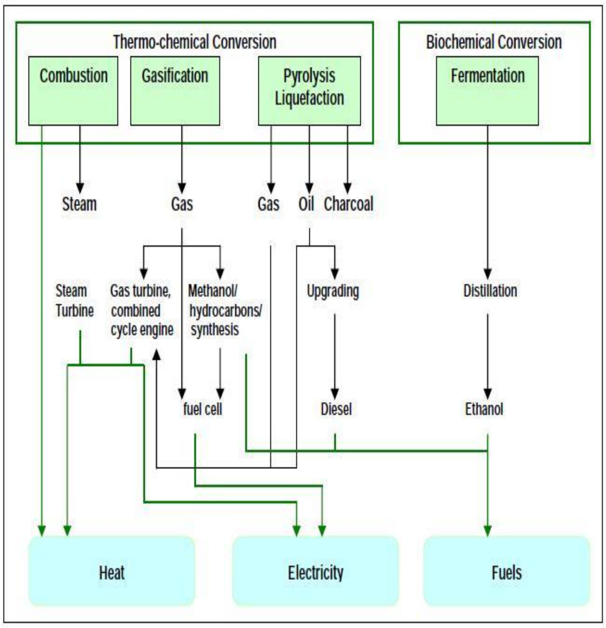



*Fig. 5: conversion routes for olive pomace*

## IV. System Design Methodology

Based on what mentioned on the previous section, the procedures followed to design a prototype of the system will be presented.

***Boiler:*** the basic components of the boiler are;

- Boiler body
- Inlet valve
- Outlet valve
- Drain valve
- Safety valve
- Pressure and temperature gauges
- Water detection unit
- Water entrance unit

The prime requirements of the boiler are:

- Corrosion resistive
- Able to bear 7-bar
- Modifiable
- Portable
- Safe
- Cheap

As shown in Fig. 6 the first step was to determine a proper body material, and then to determine its shape and thickness that enable the body to bear 7-bar pressure at last. After that a flexible design was determined in order to have wider ability of modification. Then a portable design was made, and water decoction unit were added. Last step is to find a proper method to feed water into the boiler [11].

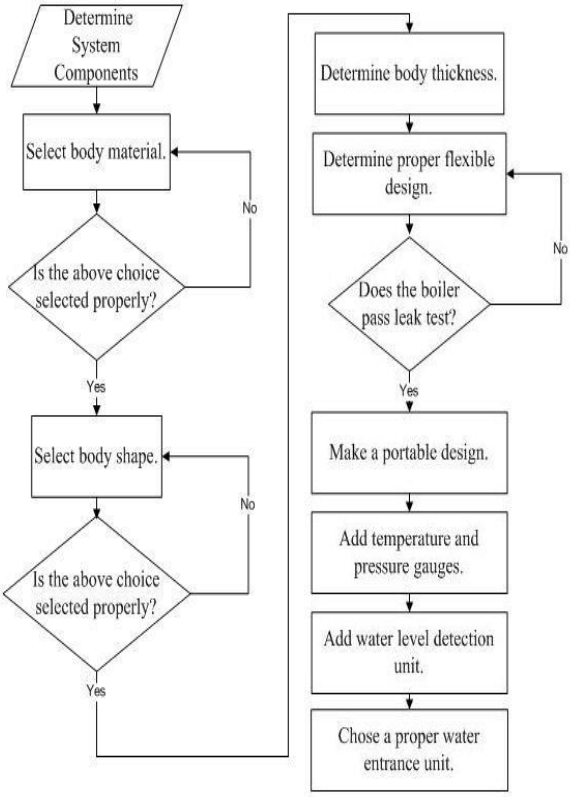
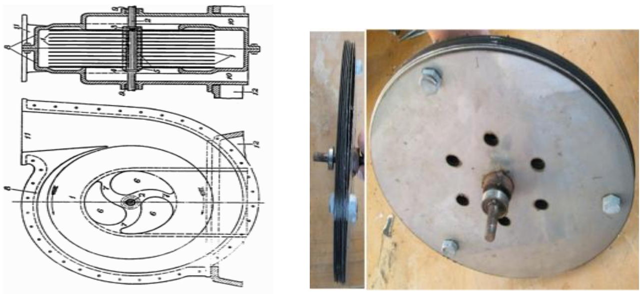



*Fig. 6: Flow chart for boiler design*

***Turbine selection:*** There are different types of steam turbine which include impulse, reaction and Tesla Turbine. In this project, Tesla Turbine was selected to convert the heat power in the output steam to mechanical energy (see Fig. 7).



*a* *b* *c*

*Fig. 7: Tesla turbine schematic (a) designed Tesla disk turbine (b front view, c top view)*

The Tesla Turbine is a bladeless centripetal flow turbine, it will be used in this project for some reasons in the following [12] and [13]:

1. It is a bladeless turbine, which makes it simple in construction
2. Low cost to produce and maintain
3. It can be operated at a wide range of working medium parameters without any danger and malfunction
4. It is not so sensitive to a partially polluted working medium, since the fluid flow is parallel to disks, so it can be operated with saturated steam
5. Does not depend on the pressure difference between the inlet and the outlet like conventional turbine
6. Overload does not affect on the Tesla turbine efficiency, since in the conventional bladed turbine a light makes for high efficiency and heavy load, which increases the slip in the turbine and lowers the efficiency, though this is not exclusive to Tesla turbine

In the other hand, there is a disadvantage of Tesla turbine that it has low rotor torque, but this disadvantage can be solved by using gears or pulleys.

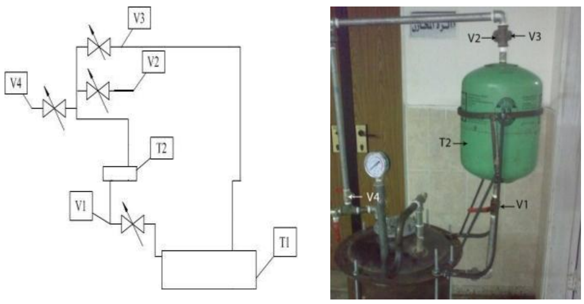



*Fig. 8: Water entrance system schematic diagram (left), photo of the system (right)*

**Water entrance unit**: The boiler prototype will provide continuous steam flow, so the boiler needs a source to compensate the water lack without pressure loses inside the boiler. The conventional way for entering water into boiler is by using pump. But pump is power consumption and will form a load on the system. A new method was created to enter the water for the boiler with very low power consumption. In this method a smaller vessel was placed over the boiler, the idea here is to equalize the pressure in the boiler and in the vessel and after that the water will flow to the boiler by head pressure effect (see Fig. 8)..

After selection of the turbine, a mechanical energy will appear on the rotation shaft; this rotation shaft will be coupled to an electric generator to produce electricity (Fig. 9).

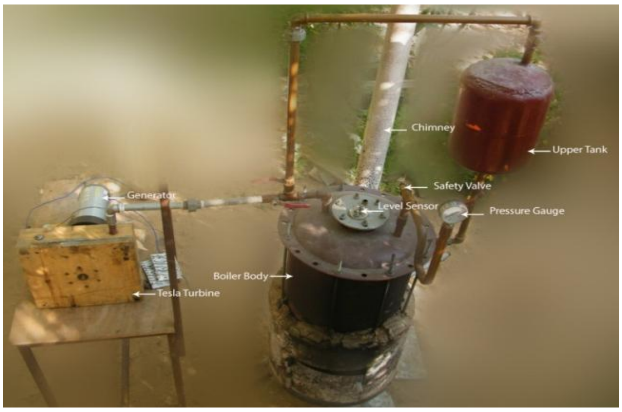



*Fig.9: the final design of the system*

## V. Experiments and Results

After completion of the boiler, turbine and electrical generator designs, experiments stage coming, and all experiments done on the system are mentioned on the following experiments.

**Boiler testing**: the first experiment done on the boiler to know if the pressure on the boiler remains constant when steam output nozzle opened. On the following the experiment procedures:

1. Fill boiler with water to the maximum level, using level detector on the electronic control unit.
2. Place the olive pomace under the boiler and burn it.
3. Monitor pressure gauge indicator until it arrives 4 bar.
4. When pressure arrives 4 bar, open steam nozzle and find what happened to the pressure gauge indicator.
5. Close the nozzle and redo procedure number four but with 7 bar pressure

After doing this experiment, all results show the boiler is able to produce high pressure steam, with high safety factor. The steam pressure remains constant when the output nozzle opened as long as the fire still burning under the boiler (Fig. 10).

*Fig. 10: Testing the boiler, steam power*

***System testing using L-Jaw coupling and DC generator experiment:*** after series of tests with deferent coupling system and generators the final experiment give the following objectives:

1. Run DC generator and find the power provided it.
2. To find the speed of the turbine shaft before and after loading the generator.
3. Using output electric power to operate resistance load (light)

***Final experiment procedures:***

1. Operate the system with previous experiments
2. Open the output steam nozzle to run the Tesla turbine and the generator
3. Use tachometer to measure the speed of the rotation shaft
4. Apply electrical load on the DC generator and record the rotating shaft speed
5. Measure the output voltage value

After doing the previous experiments, the following results were recorded:

- The turbine rotated with 1700 rpm without load at 4 bar pressure.
- DC generator gave 60 volt on 1500 rpm without load at 4 bar pressure.
- The generator gave 7 A and 60 volt with resistance load
- The prototype system produced 4 watt.

## VI. Conclusions

The designed prototype system shows, that the olive pomace is a good power source with low cost and pollution in contrast with nonrenewable energy which has very high heat value 18 kJ\kg. That means, the produced 80,000 ton of olive waste per year in Palestine cold be consumed for power generation.

Further tests are required to improve the system and to check the system efficiency to know the feasibility of the system under different conditions, and what are the elements that has the lowest efficiency in order to develop it.

In future studies the olive pomace must have a cubic shape, to facilitate the ignition of it. Furthermore a control unit will be developed to automate the feeding of the olive pomace.

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